ITRAC-2:

2nd Advanced Training Course on Illicit Trafficking and Radiological Consequences with NUCLEONICA, ITU Karlsruhe, 22-24th April 2009

Nucleonica Data Centre (www.nucleonica.net)

J. MAGILL

European Commission, Joint Research Centre,

Institute for Transuranium Elements,

Postfach 2340, 76125 Karlsruhe, Germany

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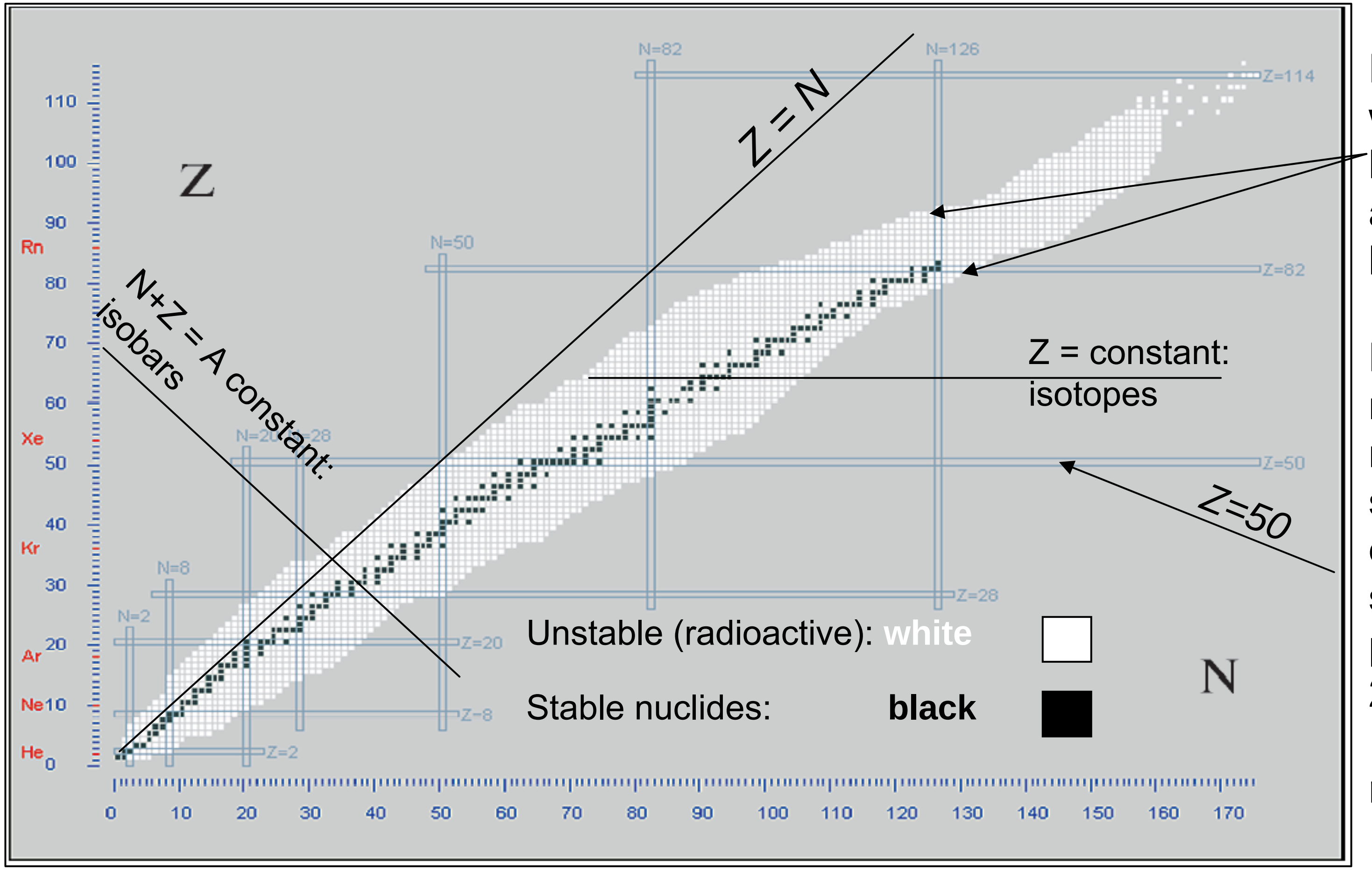
It all started with the Karlsruhe Nuclide Chart…

What is a Nuclide Chart?



Extremities of the white regions are known as the proton and neutron drip-lines

Nuclei with even numbers of protons and neutrons are more stable. The stability is extremely significant for special numbers of protons and neutrons i.e. 2, 8, 20, 28, 50, 82,and 126. These are the **magic numbers**

For light nuclei, N = Z, but with increasing Z, N > Z, i.e. the number of neutrons increases more strongly than the number of protons. Note that the stable isotopes lie within a relatively narrow range indicationg that the neutron to proton ratio must have a certain value or range to be stable

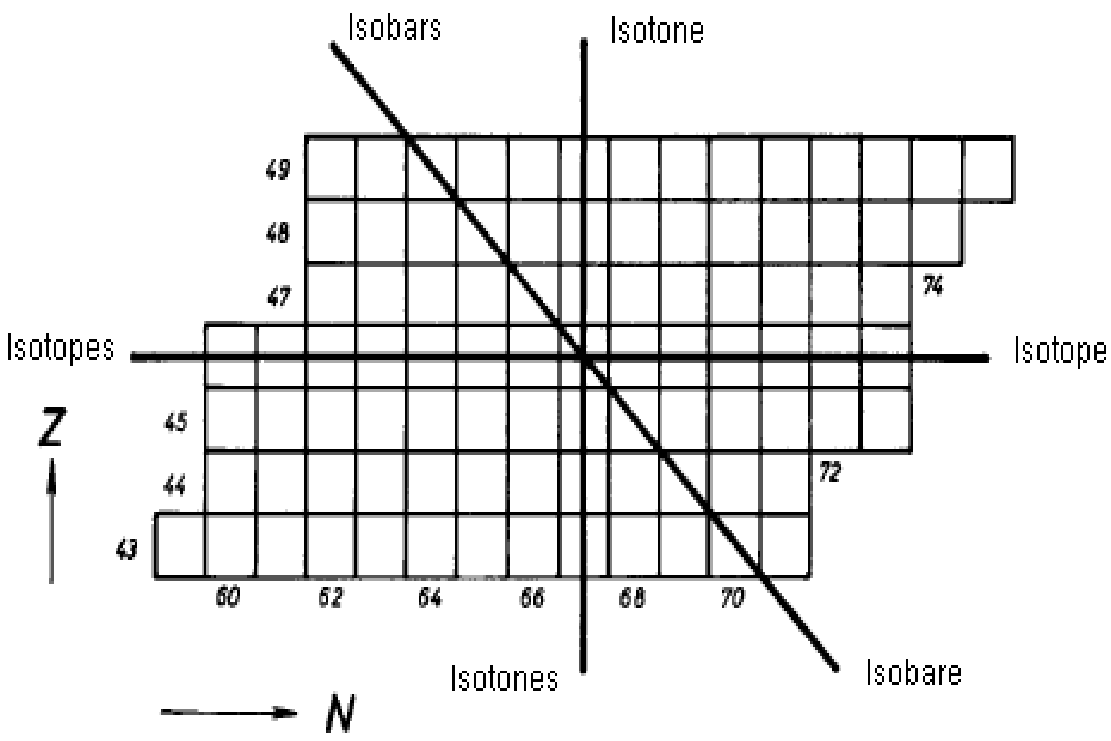
The visualisation of the Nuclides

Nuclide : *A type of atom specified by its atomic number, Z, mass number, A, and energy state.*

Isotopes : *meaning at the same place in the periodic table ➡ nuclides with same Z.*

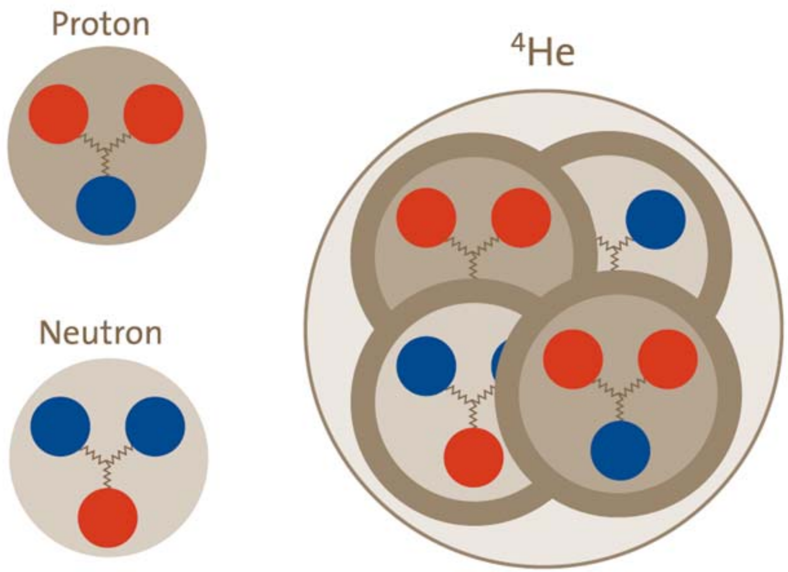
Isotones : *nuclides with the same N (=A-Z).*

Isobars : *nuclides with the same A.*



The Quark Structure of Nuclei

Quarks were proposed in independently by Gell-Mann and Zweig in 1964 as the basic building blocks of matter. The word "quark" was coined by Gell-Mann based on the sound made by ducks. Later, he discovered the use of the word quark in James Joyce's book Finnegan's Wake.

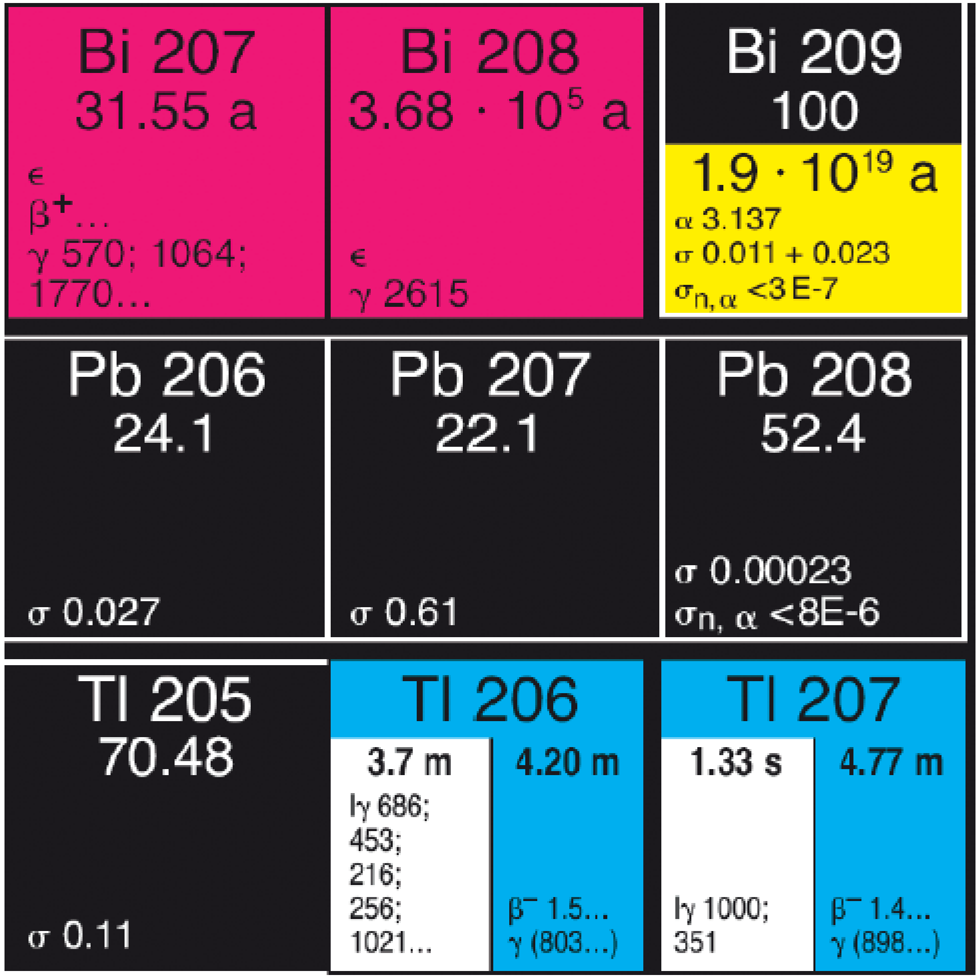


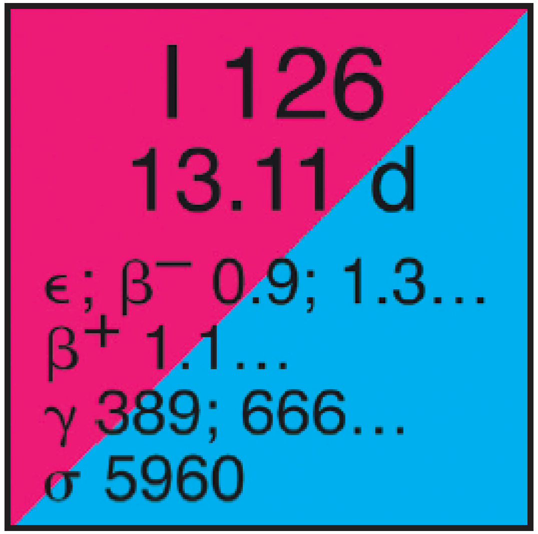
The quark structure of nucleons: the proton consists of two up quarks (red) and one down quark (blue) and the neutron one up and two down quarks held together by powerful gluon fields. (Right) the overlap of protons and neutrons in a helium-4 nucleus based on the static sizes of particles © American Physical Society, 2003.

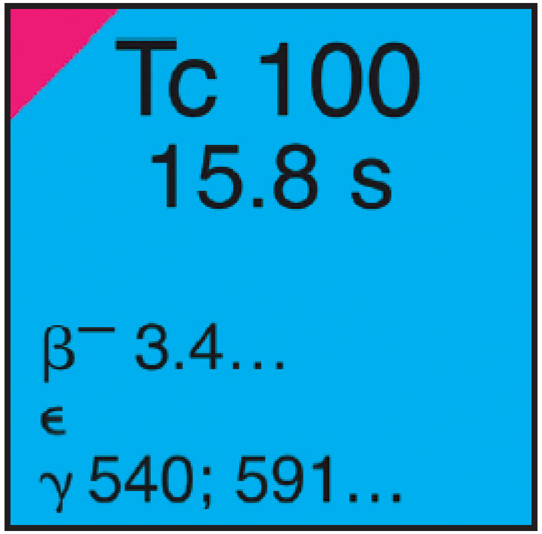
Use of colours in the Karlsruhe Nuclide Chart:

Already in the first Edition of the Karlsruhe Chart of the Nuclides, colours were used to indicate the decay modes

black = stable nuclide;
yellow = α-decay;
red = ß+ decay or electron capture;
blue = ß- decay;
white = isomeric transition).



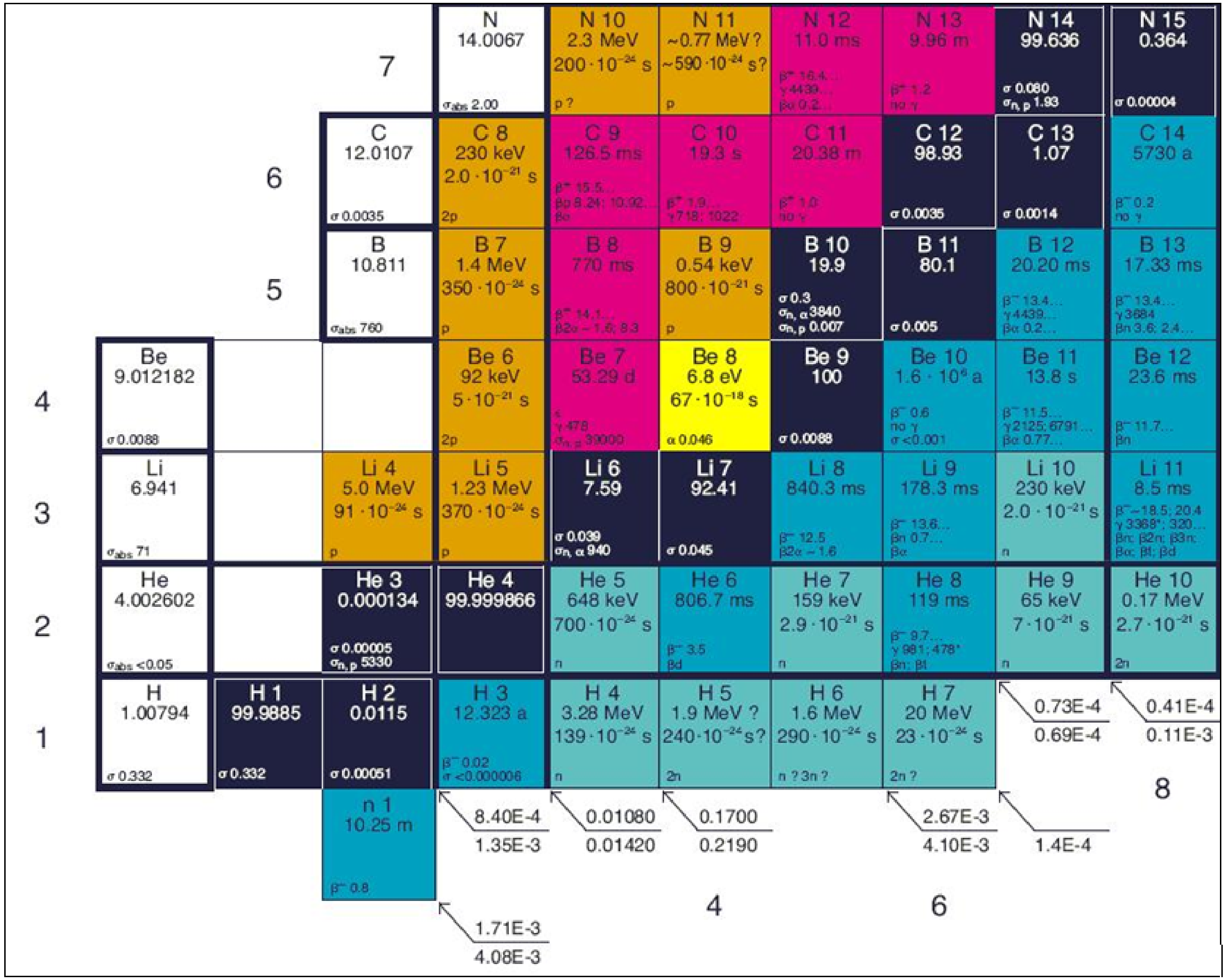




When a nuclide has more than one decay mode, coloured triangles give a rough indication of the branching ratios of each mode.
Left: The large triangles used in I-126, indicate the branching ratios for electron capture ε and $ß^-$ emission are ≥ 5 %, but ≤ 95 % respectively.

Note that the decay modes are listed in the order of decreasing frequency.

Right: The small triangle used in Tc-100 indicates that the ε branching ratio is ≤ 5 %. The corresponding branching ratio for $ß^-$ emission ≥ 95 %.


7
N 14.0067
N 10 2.3 MeV
N 11 ~0.77 MeV ?
N 12 11.0 ms
N 13 9.96 m
N 14 99.636
N 15 0.364
6
C 12.0107
C 8 230 keV
C 9 126.5 ms
C 10 19.3 s
C 11 20.38 m
C 12 98.93
C 13 1.07
C 14 5730 a
5
B 10.811
B 7 1.4 MeV
B 8 770 ms
B 9 0.54 keV
B 10 19.9
B 11 80.1
B 12 20.20 ms
B 13 17.33 ms
4
Be 9.012182
Be 6 92 keV
Be 7 53.29 d
Be 8 6.8 eV
Be 9 100
Be 10 1.6 · 10⁶ a
Be 11 13.8 s
Be 12 23.6 ms
3
Li 6.941
Li 4 5.0 MeV
Li 5 1.23 MeV
Li 6 7.59
Li 7 92.41
Li 8 840.3 ms
Li 9 178.3 ms
Li 10 230 keV
Li 11 8.5 ms
2
He 4.002602
He 3 0.000134
He 4 99.999866
He 5 648 keV
He 6 806.7 ms
He 7 159 keV
He 8 119 ms
He 9 65 keV
He 10 0.17 MeV
1
H 1.00794
H 1 99.9885
H 2 0.0115
H 3 12.323 a
H 4 3.28 MeV
H 5 1.9 MeV ?
H 6 1.6 MeV
H 7 20 MeV
0.73E-4
0.69E-4
0.41E-4
0.11E-3
8
n 1 10.25 m
8.40E-4
1.35E-3
0.01080
0.01420
0.1700
0.2190
2.67E-3
4.10E-3
1.4E-4
1.71E-3
4.08E-3
4
6

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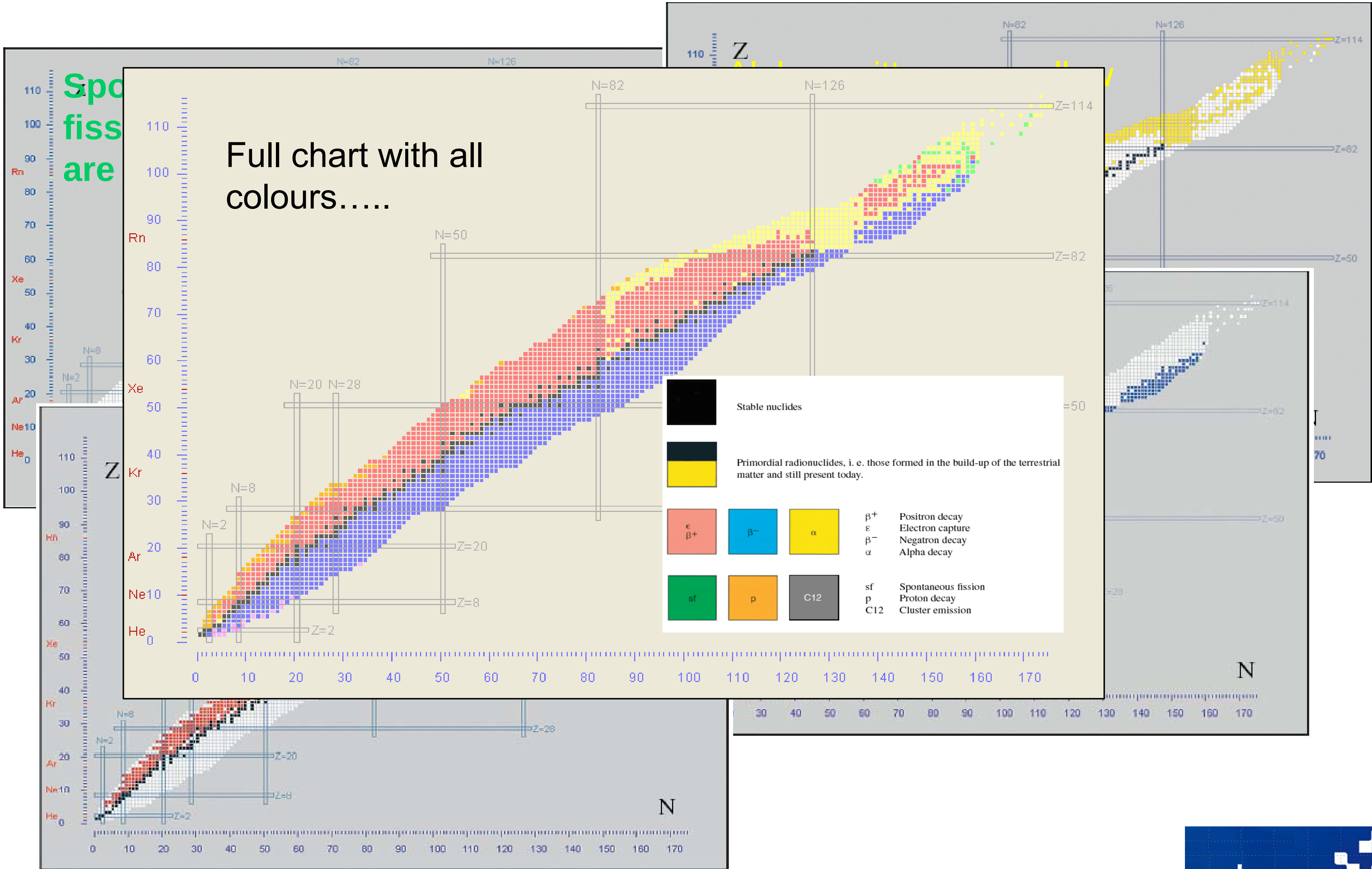
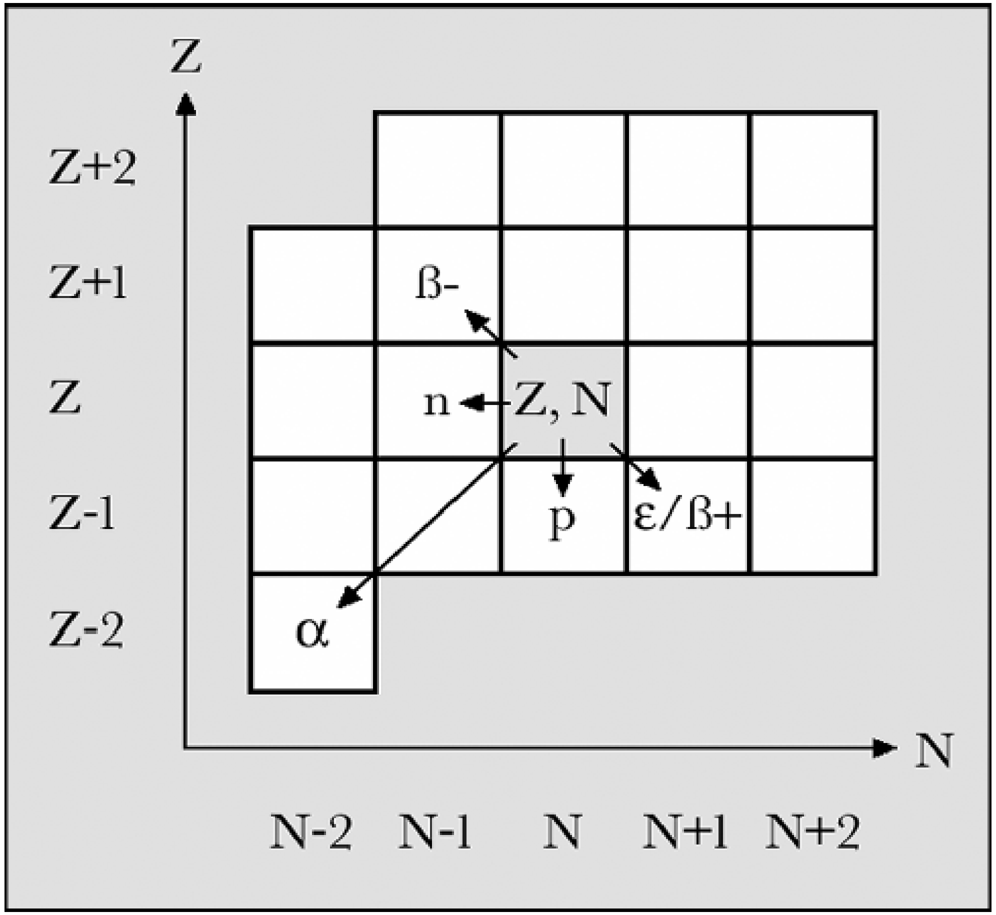
What the colours mean…

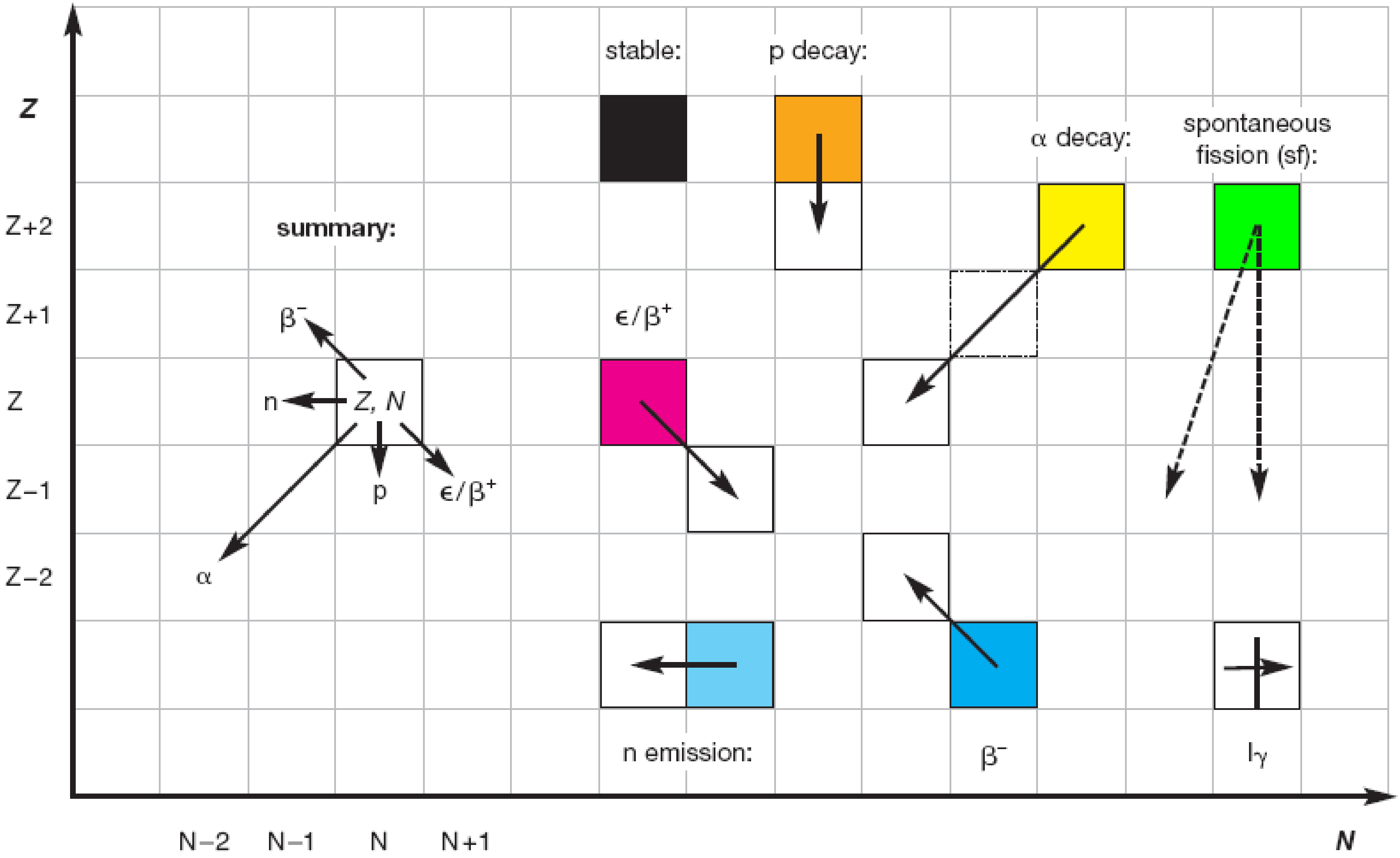


Radioactive Decay Processes

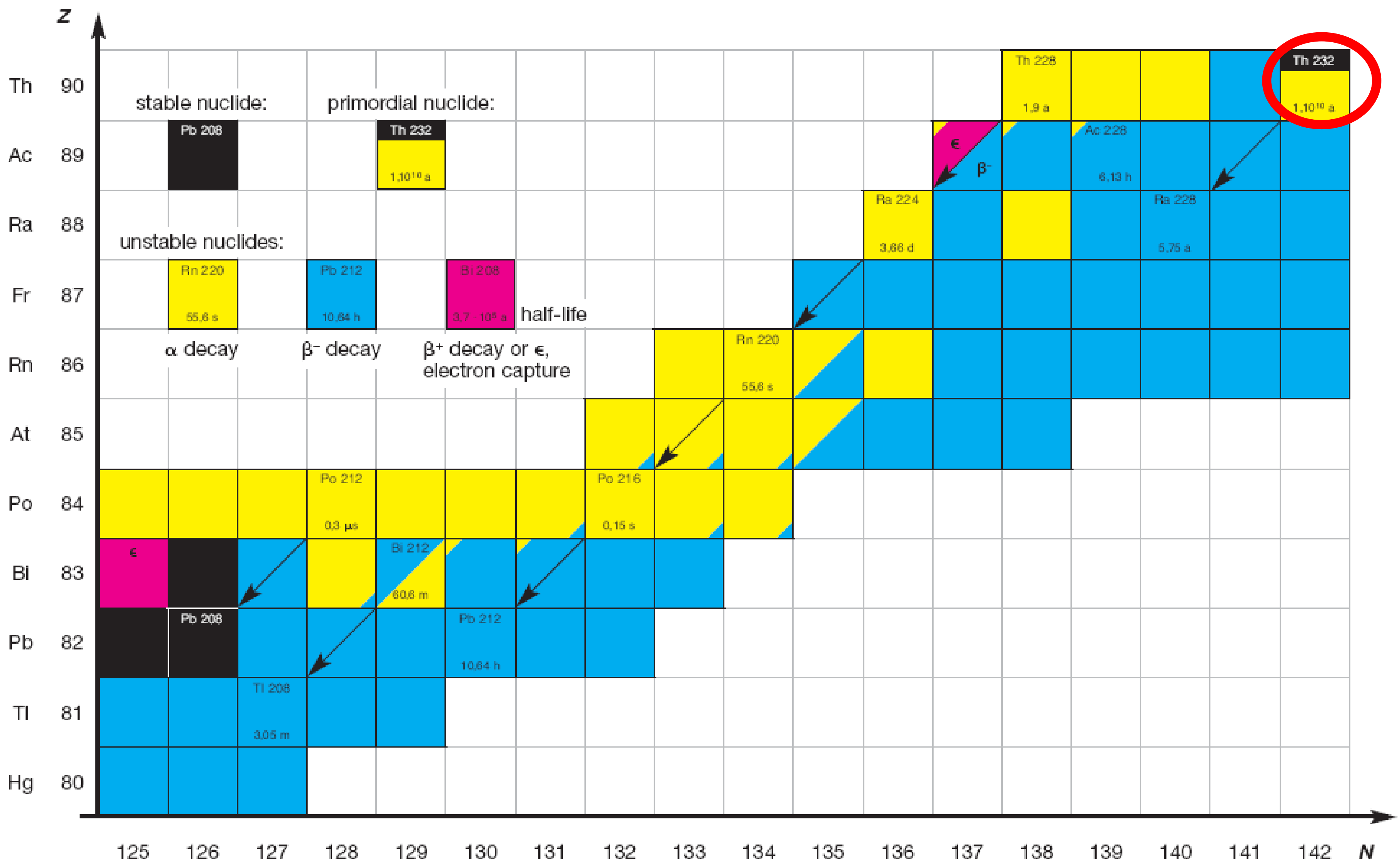
Nuclear decay processes on the nuclide chart. A nuclide with “co-ordinates” *Z,N* transforms to the nuclide *Z´,N´* through the decay processes shown



Radioactive Decay on the Nuclide Chart…

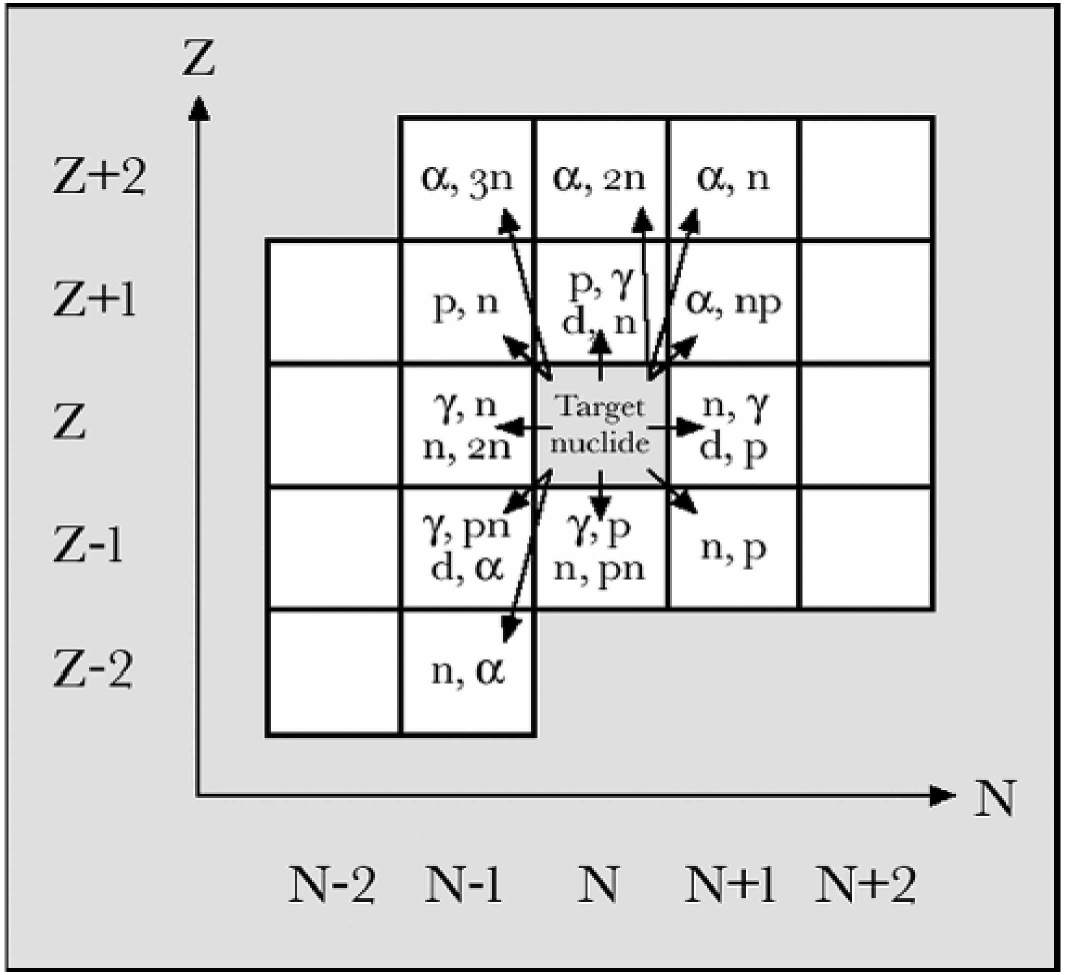


Karlsruher Nuklidkarte: Th232 decay chain



Nuclear Reactions:

Activation processes and nuclear reactions on the nuclide chart. A target nuclide with co-ordinates *Z*, *N* transforms to the nuclide *Z´*,*N´* through the processes shown



"Karlsruher Nuklidkarte"

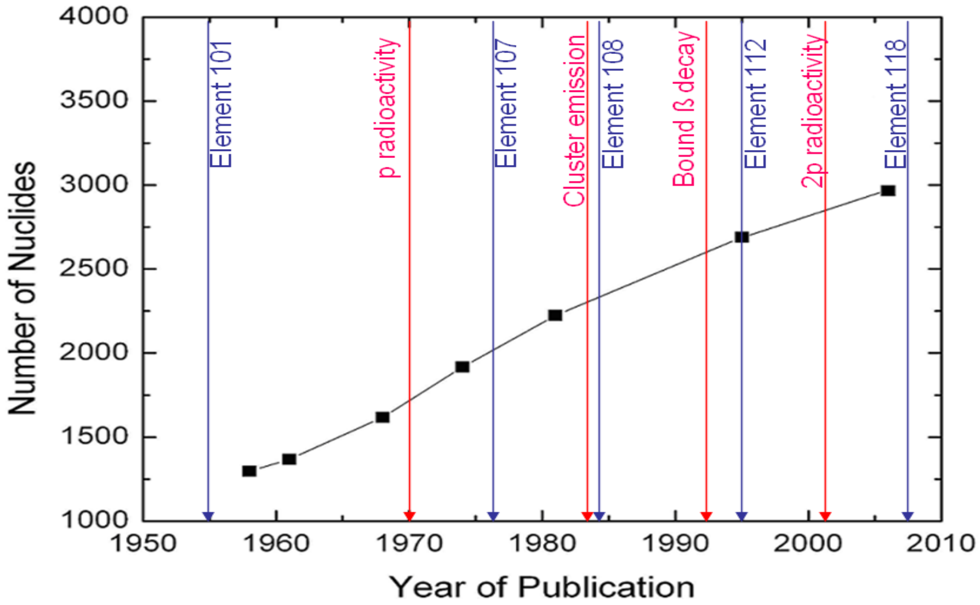
G.T. Seaborg, 1951

W. Seelmann-Eggebert
"El profesor alemán"

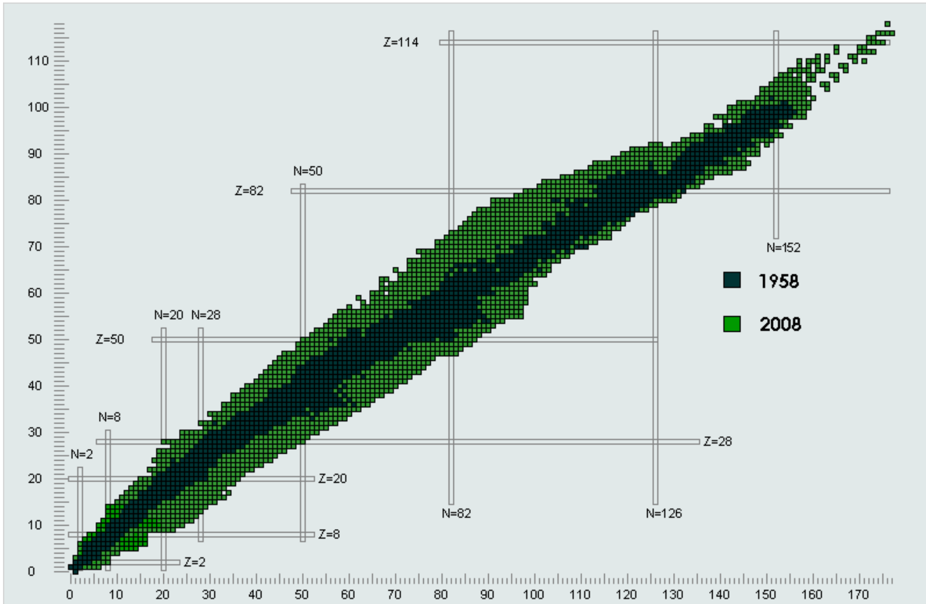
- Representation of nuclides in a proton/neutron map system (Fea 1935, Seaborg, 1940, Segrè 1945)
- 1958 first edition of the "Karlsruher Nuklidkarte" W. Seelmann-Eggebert and G. Pfennig from the Karlsruhe Radiochemical Institute.
- 267 stable and 1030 radionuclides for 4 decay modes

Number of Nuclides for the 7th edition: 2962 ground states and 692 isomers

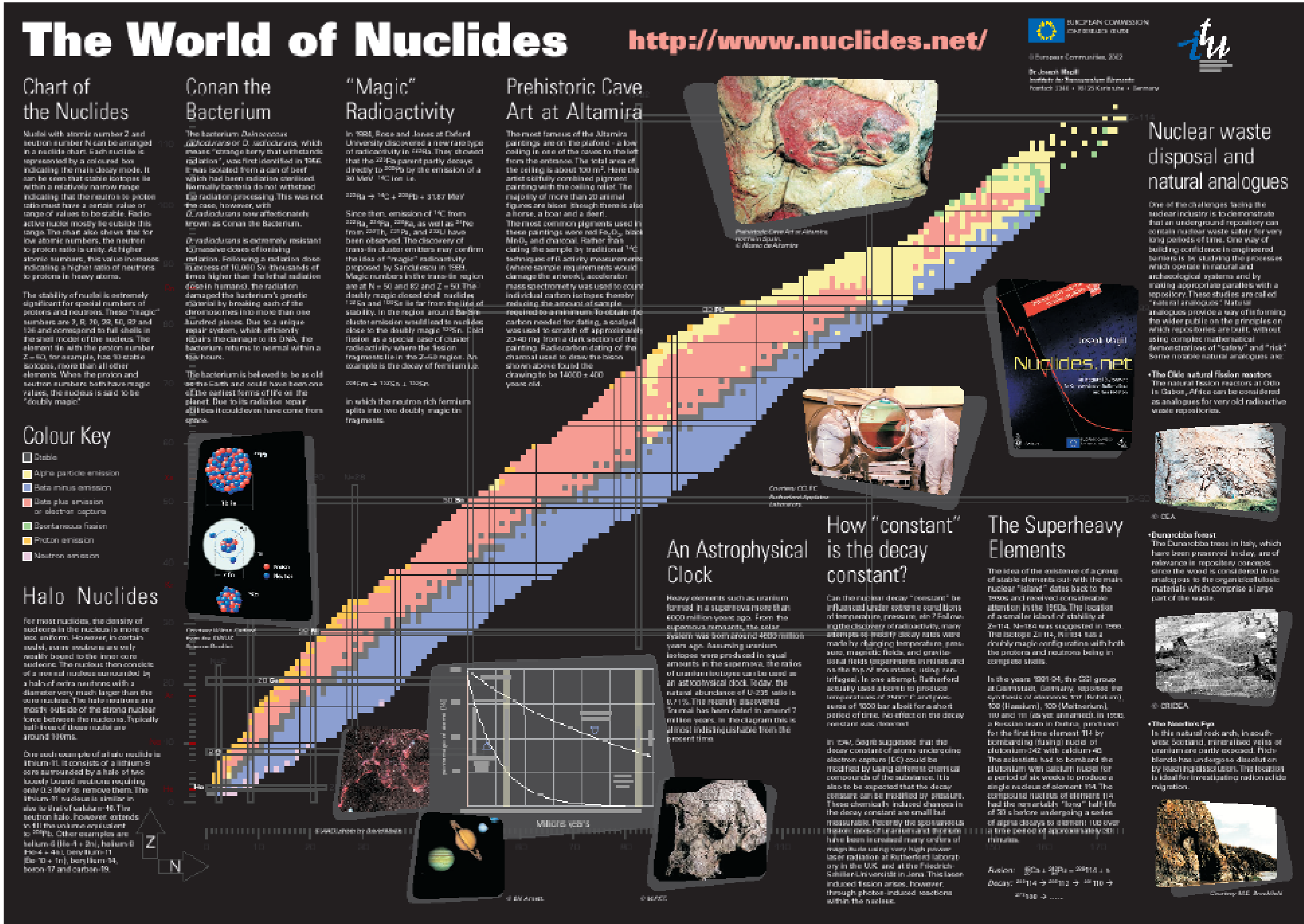
Progress in nuclear structure knowledge



Number of Nuclides in the KN editions



- Between the first edition and the 7th edition the number of nuclides has increased from 1300 to 3000. Theoretical predictions are expecting 6000 possible ground-state nuclides


The World of Nuclides
http://www.nuclides.net/
Chart of the Nuclides
Conan the Bacterium
"Magic" Radioactivity
Prehistoric Cave Art at Altamira
Nuclear waste disposal and natural analogues
Colour Key
Halo Nuclides
An Astrophysical Clock
How "constant" is the decay constant?
The Superheavy Elements
Nuclides.net
Millions years
Z
N

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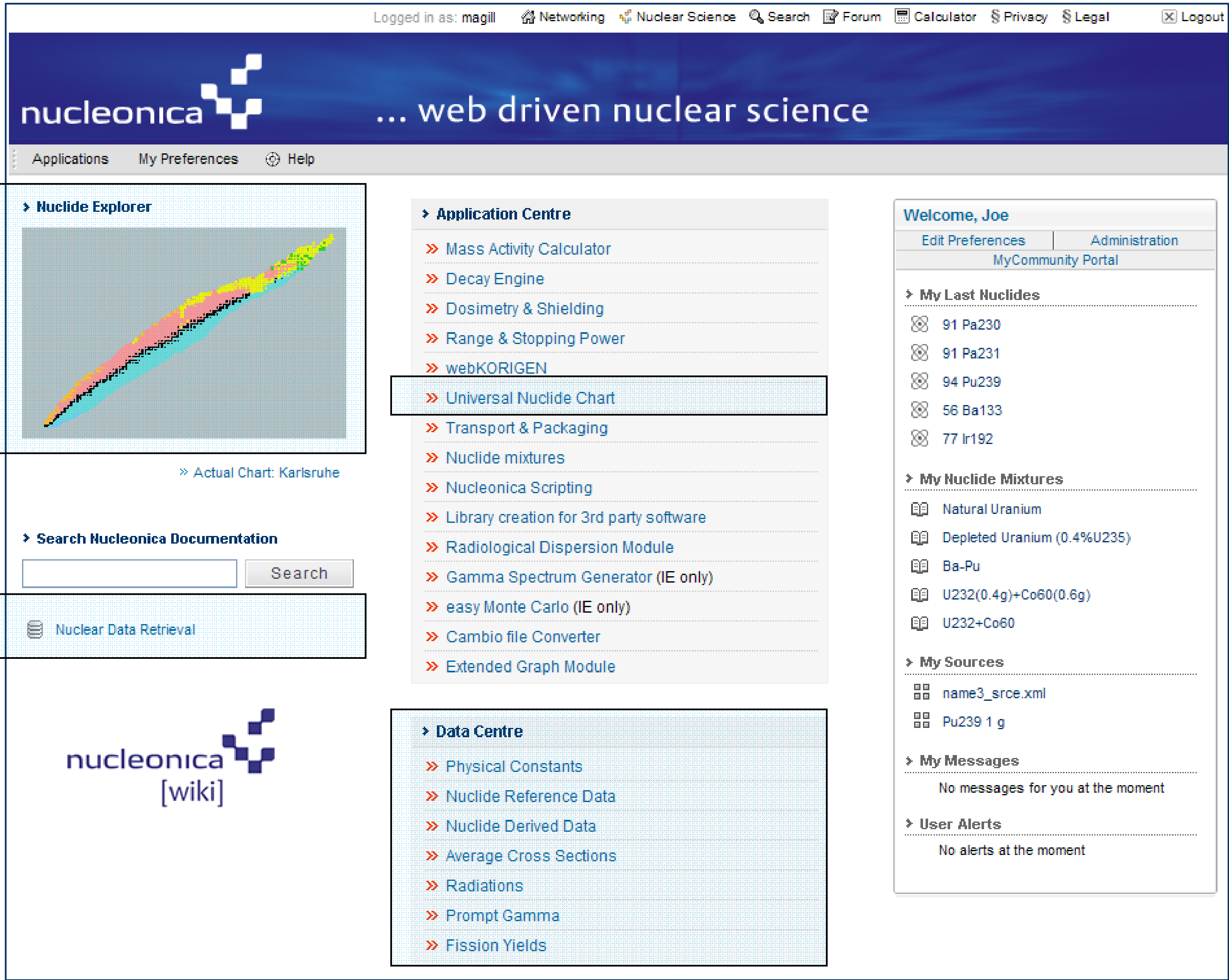
Where do we find nuclear data in Nucleonica?



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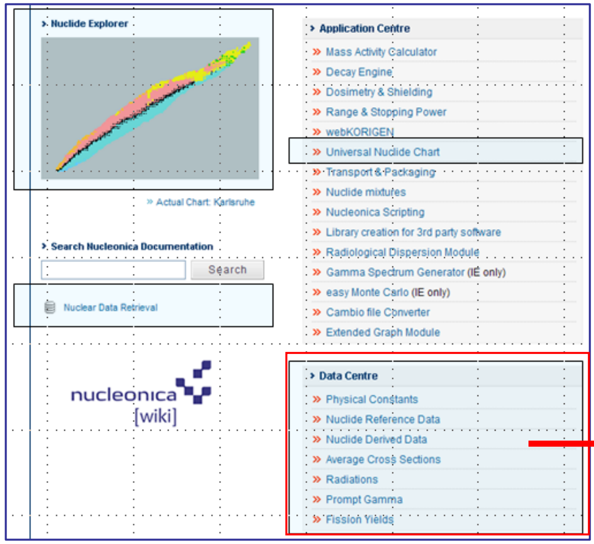

π **Physical Constants**

Physical Constants | Conversion Factors | Prefixes / Greek Alphabet | Radiological Limits

Radiological Limits

Workers | Apprentices and Students | Members of the Public

Workers

Dose Limits for exposed workers	Euratom	ICRP	IAEA	Germany
Limit on effective dose for exposed workers in a consecutive 5 years period:	100 mSv	20 mSv/y	20 mSv/y	20 mSv/y
Maximum effective dose in any single year:	50 mSv/y	50 mSv/y	50 mSv/y	50 mSv/y
Equivalent dose limit to the foetus, accumulated over the period of time between declaration of pregnancy to the delivery date:	1 mSv	2 mSv		1 mSv
Pregnant woman				2 mSv/m
Total work life (50 y)				400 mSv
Partial body exposure:				
Limit on equivalent dose for the lens of the eyes:	150 mSv/y	150 mSv/y	150 mSv/y	150 mSv/y
Limit on equivalent dose for the skin:	500 mSv/y	500 mSv/y	500 mSv/y	500 mSv/y
Limit on equivalent dose for the hands, forearms, feet and ankles:	500 mSv/y	500 mSv/y	500 mSv/y	500 mSv/y

Name
Alpha
Beta
Gamma
Delta
Epsilon
Zeta
Eta
Theta
Iota
Kappa
Lambda
Mu
Nu
Xi
Omicron

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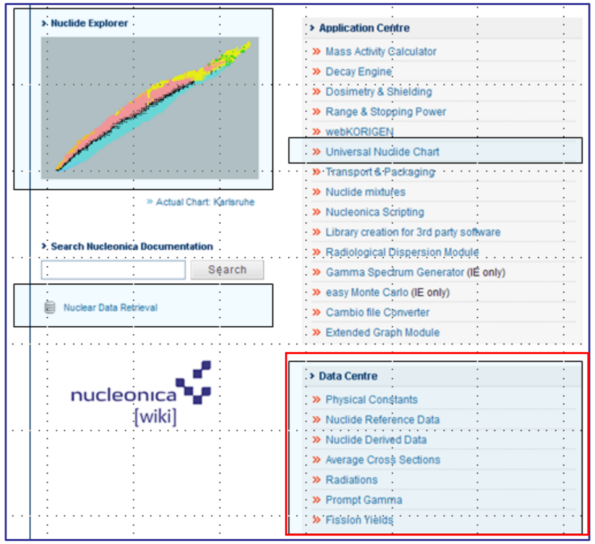

Pu239
2.4E4 y

Fission Yields

94 Plutonium

Current Chart: Karlsruhe

Element: Pu Mass: 239

Select | Fission Yields

Library: JEFF-3.1
Type of Fission: Thermal fission
Total number of fission products: 25

	Nuclide	Half-life	Independent Yield	Error	Cumulative Yield	Error
Compare	55 Cs 135	2.3 (± 3) My	8.54E-05	3.04E-05	7.38E-02	2.36E-03
Compare	55 Cs 133	Stable	2.26E-07	8.21E-08	6.99E-02	1.26E-03
Compare	55 Cs 137	30.04 (± 3) y	4.57E-03	1.62E-03	6.59E-02	8.03E-04
Compare	55 Cs 138	33.41 (± 18) m	4.27E-03	1.44E-03	5.94E-02	1.61E-03
Compare	55 Cs 139	9.27 (± 5) m	2.30E-02	5.12E-03	5.72E-02	9.18E-04
Compare	55 Cs 140	1.062 (± 5) m	2.77E-02	4.64E-03	4.45E-02	1.12E-03
Compare	55 Cs 141	24.94 (± 6) s	2.92E-02	4.50E-03	3.38E-02	1.73E-03
Compare	55 Cs 142	1.70 (± 2) s	1.52E-02	3.67E-03	1.63E-02	2.48E-03
Compare	55 Cs 143	1.791 (± 7) s	5.95E-03	1.87E-03	6.06E-03	1.61E-03
Compare	55 Cs 138m	2.91 (± 8) m	6.06E-03	2.04E-03	6.06E-03	1.85E-03
Compare	55 Cs 144	994 (± 4) ms	5.69E-04	2.02E-04	8.62E-04	2.21E-04
Compare	55 Cs 136	13.03 (± 7) d	5.88E-04	2.07E-04	7.60E-04	2.15E-04
Compare	55 Cs 144m	1.0 (± 0) s	5.69E-04	2.02E-04	5.69E-04	1.99E-04
Compare	55 Cs 136m	19 (± 2) s	3.45E-04	1.21E-04	3.45E-04	1.21E-04
Compare	55 Cs 145	594 (± 13) ms	1.81E-04	6.42E-05	1.81E-04	6.38E-05
Compare	55 Cs 135m	53 (± 2) m	5.22E-05	1.86E-05	5.22E-05	1.86E-05

Graph

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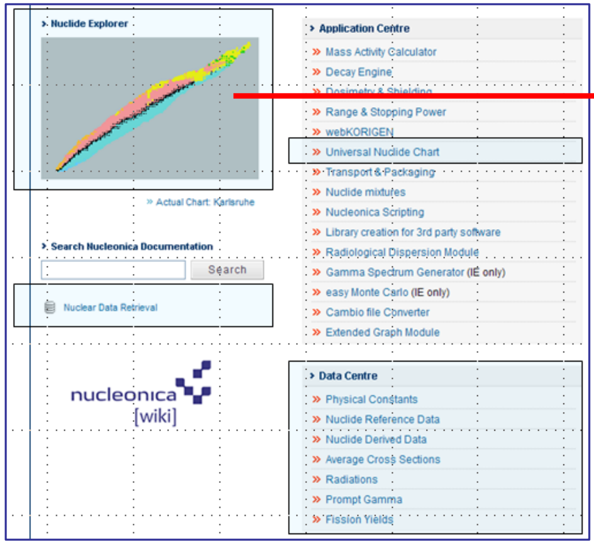
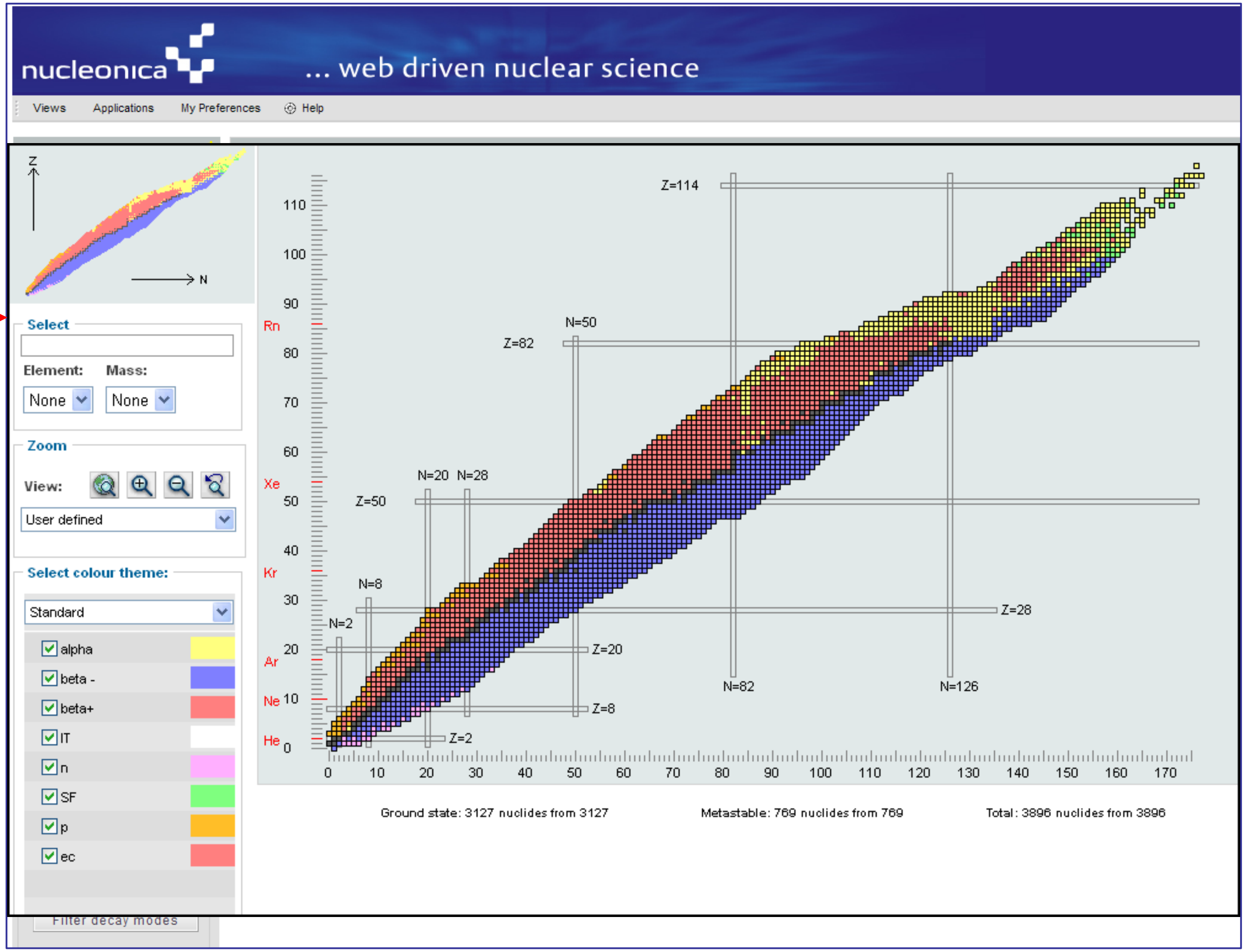
itu Institute for Transuranium Elements

Nuclide Explorer…





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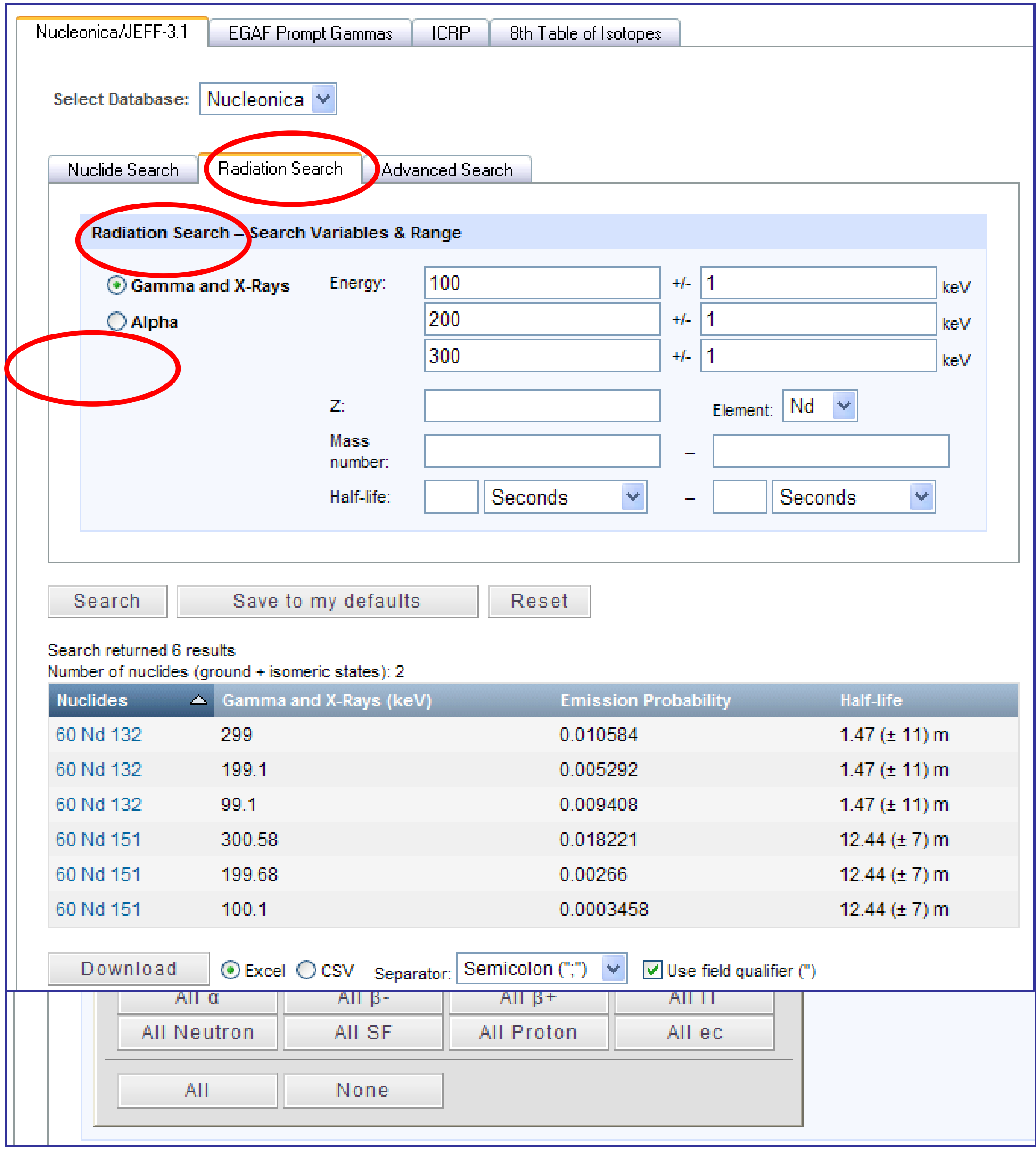
Nuclear Data Retrieval…



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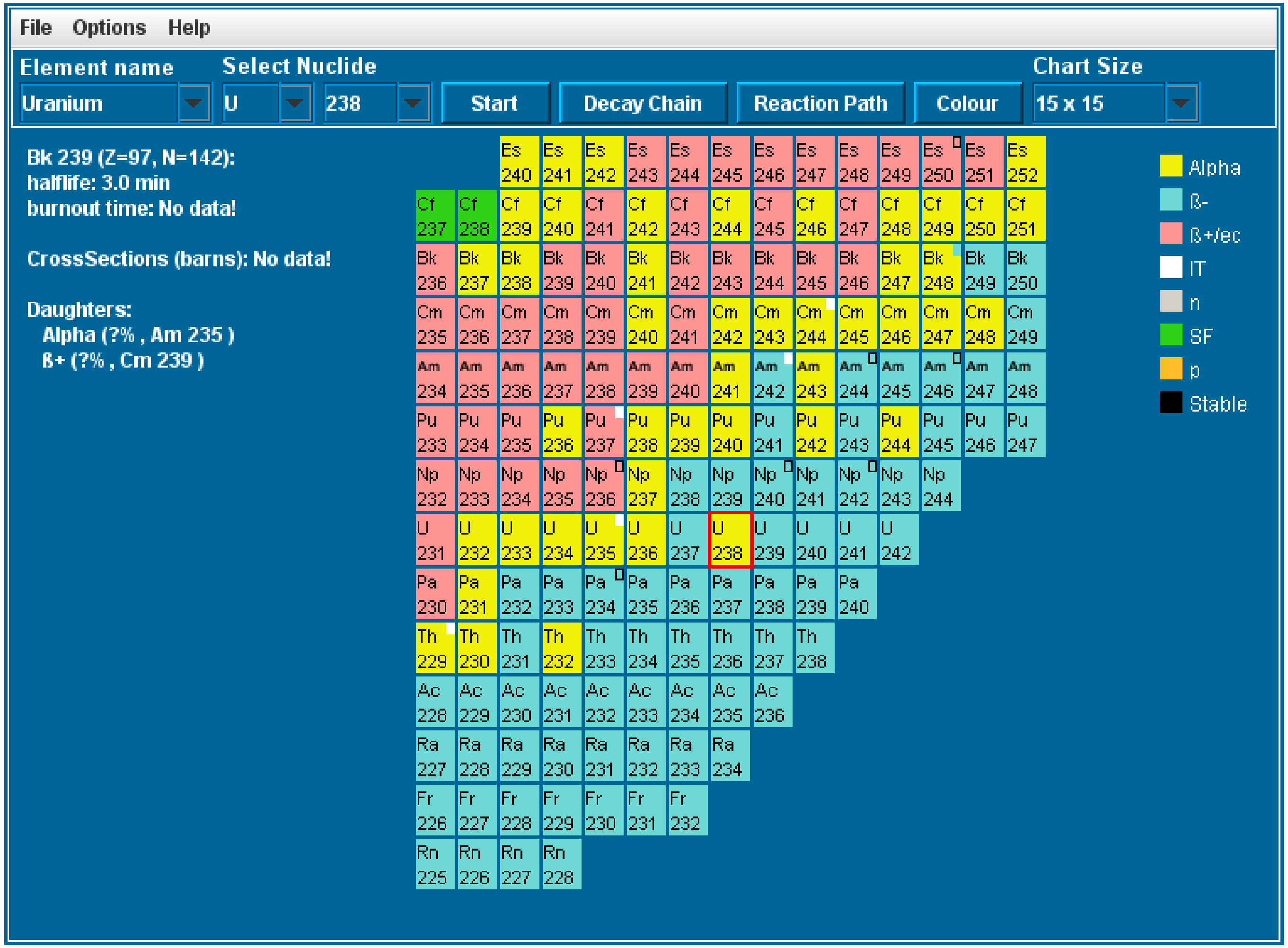

Try it out! http://www.nucleonica.net/Applet/universalchart.aspx

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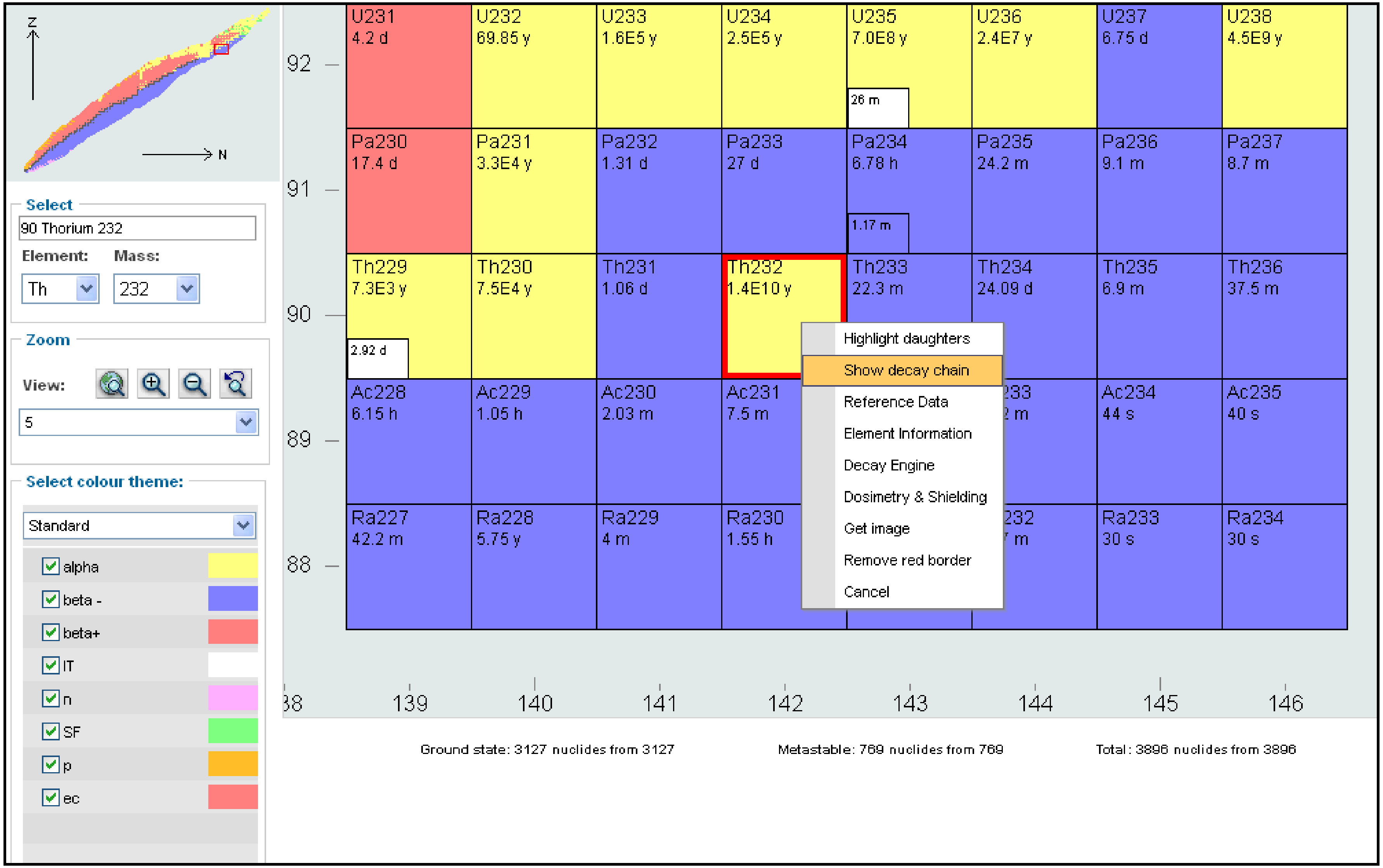

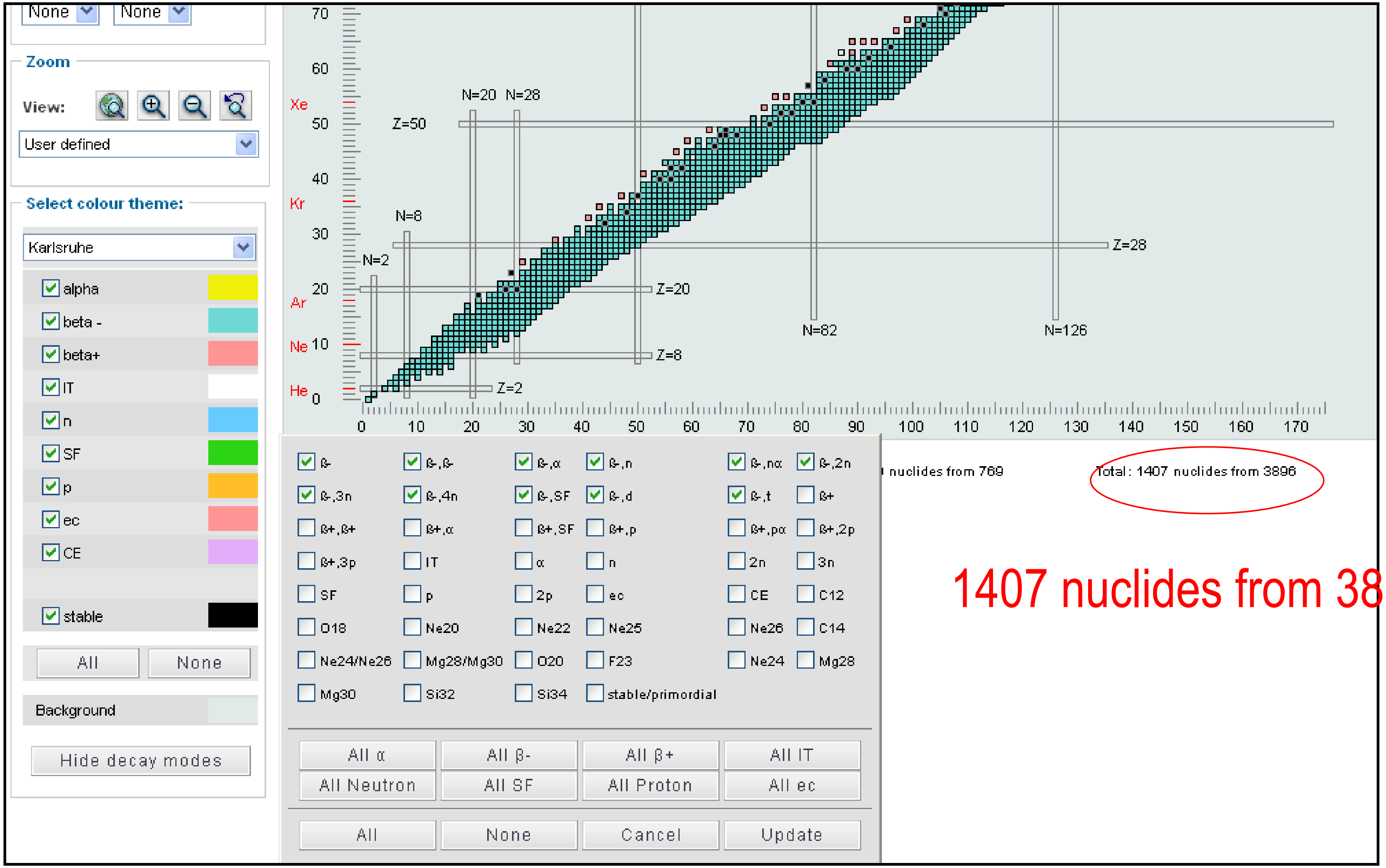
None
None
Zoom
View:
User defined
Select colour theme:
Karlsruhe
alpha
beta -
beta+
IT
n
SF
p
ec
CE
stable
All
None
Background
Hide decay modes
Xe
Kr
Ar
Ne
He
N=2
N=8
N=20
N=28
N=82
N=126
Z=2
Z=8
Z=20
Z=28
Z=50
ß-
ß-,ß-
ß-,α
ß-,n
ß-,nα
ß-,2n
ß-,3n
ß-,4n
ß-,SF
ß-,d
ß-,t
ß+
ß+,ß+
ß+,α
ß+,SF
ß+,p
ß+,pα
ß+,2p
ß+,3p
IT
α
n
2n
3n
SF
p
2p
ec
CE
C12
O18
Ne20
Ne22
Ne25
Ne26
C14
Ne24/Ne26
Mg28/Mg30
O20
F23
Ne24
Mg28
Mg30
Si32
Si34
stable/primordial
All α
All β-
All β+
All IT
All Neutron
All SF
All Proton
All ec
All
None
Cancel
Update
nuclides from 769
Total: 1407 nuclides from 3896
1407 nuclides from 3896

Thanks!

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